THE EDGE MOOR
WATER TUBE BOILER

1920

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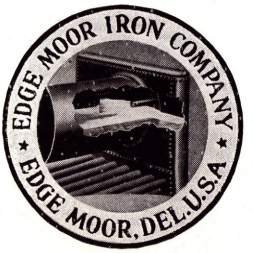

REGISTERED PROFESSIONAL ENGINEER
GEORGE W. O'NEILL
MECHANICAL
NOVA SCOTIA
April 25/30

BULLETIN NUMBER SIXTY-TWO

1920

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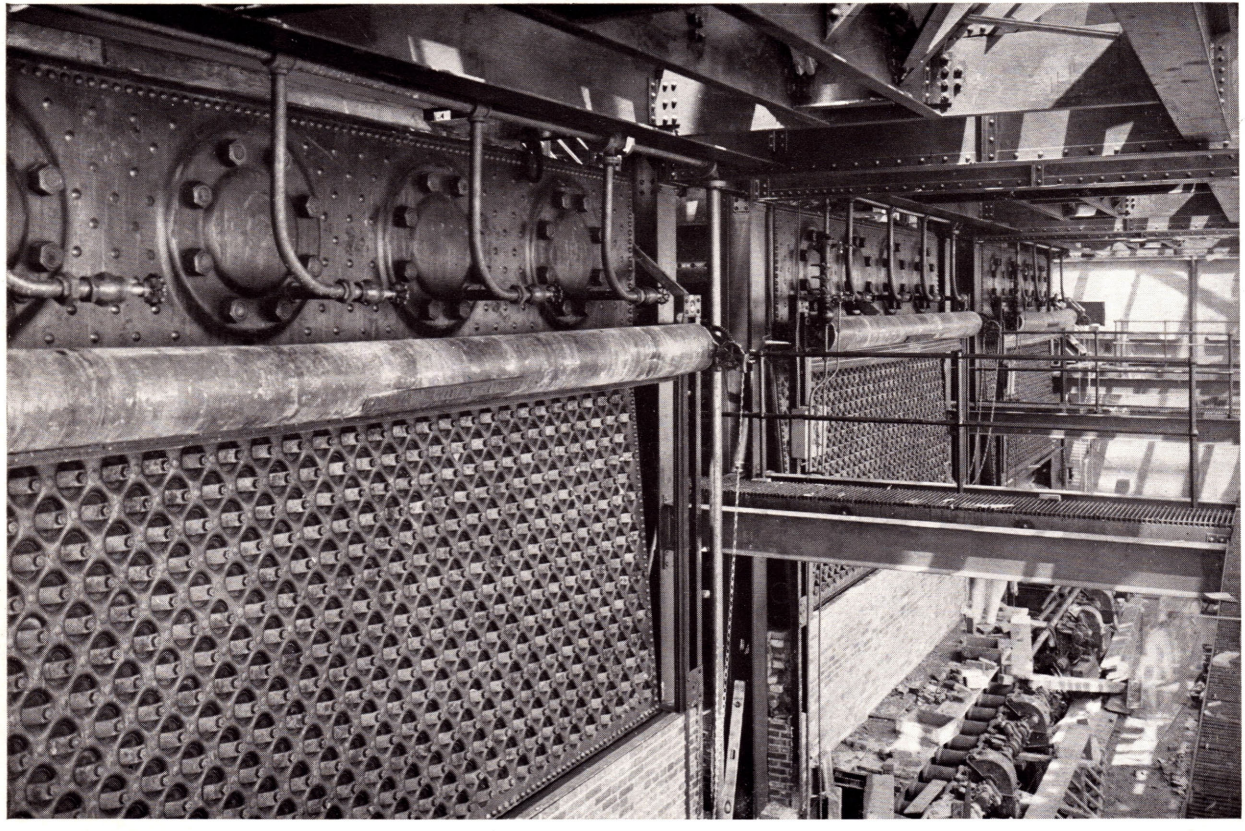


Large Edge Moor boilers in the Westport Station of the Consolidated Gas, Electric Light and Power Company, Baltimore, Md. Each boiler has 10,490 sq. ft. of water-heating surface

EDGE MOOR WATER TUBE BOILER

Development and Theory

EVERY highly developed art passes through two stages of progress and has its beginnings in some new conviction; as, for example, power for industrial purposes can be generated from steam. In the earlier stage efforts are necessarily concentrated on the discovery of means to realize this conviction, and the appliances found "to work" are generally more or less crude. In the later stage the efforts are shifted to the development of refinements to overcome objectionable results, to improve quality and to increase quantity. The construction of the modern high-pressure boiler has followed a similar line of development.

At first, efforts were concentrated principally on the development of the now typical arrangements of the heating surface together with those structural details that are necessary for safety and maintenance. In recent years, the efforts have been confined to those seemingly minor details that affect that very important result—the all-over cost of power.

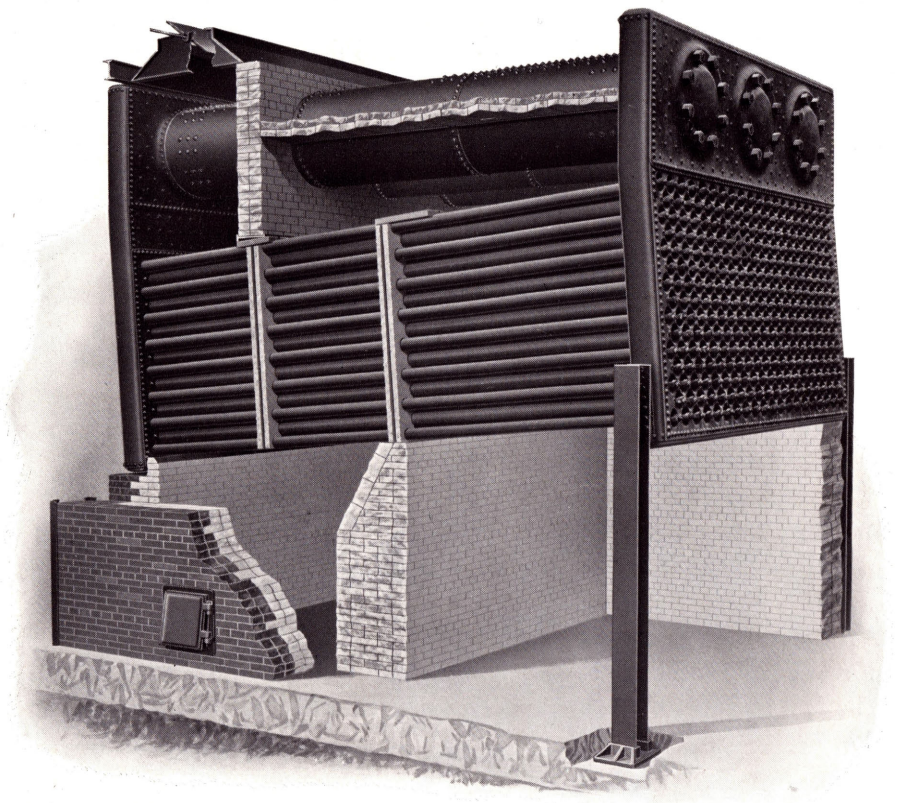
Since the boiler is an auxiliary to the steam engine, their historical development, as far as steam pressures are concerned, has been parallel. The first steam engine of the piston type actually constructed, the invention of Newcomen and Cawley which seems to have been patented in 1705, did not make use of the "pushing power" of steam. The top of the piston was always open to the atmosphere while the cylinder space below was alternately filled with steam, at about atmospheric pressure, which was later condensed to "lift off" the back pressure, thus causing motion of the piston. This was really a vacuum engine.

Later, in 1765, James Watt invented the separate condenser, put a cylinder head on the Newcomen engine, admitted the steam between cylinder head and piston, and thus produced the first pressure engine. Incidentally, he laid the foundation for the pressure boiler.

Forty years later, steam pressures had crawled from that of the atmosphere to about five pounds per square inch! It was a pressure

even modestly less than this that constituted the motive power for the first voyage of a steamboat—the Clermont in 1807.

Between 1850 and 1860, according to Thurston, the customary pressures for new engines was from 20 to 25 pounds. In 1876, at the Centennial Exhibition at Philadelphia, the fourteen boilers there exhibited, which represented the best practice at that time, were tested at 70 pounds.



Note the header construction, the horizontal drums, the straight, inclined tubes, the elliptical handholes and the efficient cross baffling

In 1900, 150 pounds pressure was considered high for land plants, while today the customary pressure for the larger plants is from 175 to 250 pounds per square inch.

But high pressure alone does not distinguish the modern boiler from its predecessors. The tremendous increase in manufacturing, and in the domestic and industrial uses of electric power has created an insistent

demand for those refinements which have to do with cost of production, certainty of service and economical use of property. Thus, the fact that a boiler gave good satisfaction twenty-five years ago argues nothing as to its suitability for the needs of the present day.

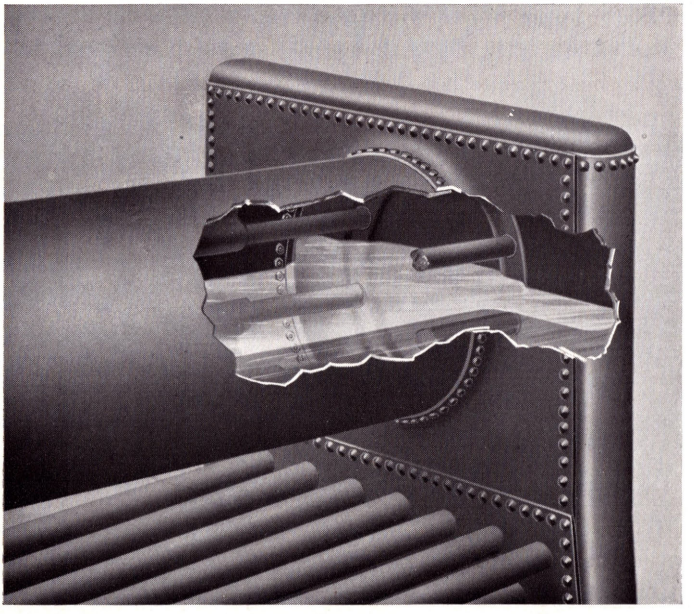
The Edge Moor boiler was designed to meet modern conditions. The first one of this type was built in our shops in 1895 and proved highly satisfactory. Since then there have followed the natural improvements in structural details and in methods of manufacturing, but the original principle, which will be explained presently, has been adhered to.

Reduced to its simplest form, a steam boiler is a plate of metal with hot gas on one side and cold water on the other, the terms hot and cold being merely relative. As is well known, when the temperature of the hot side of a plate remains constant, the amount of heat which will be conducted through the plate will vary with the temperature of the cold side. That is, by lowering the temperature of the cold side more heat will be transmitted, and vice versa. Now the temperature of the cold side of the plate is dependent on the conductivity of the substance in contact with that side; for, if the heat that passes through the plate is conducted away rapidly, the temperature of the cold side will be relatively low but, on the other hand, if the heat is conducted away slowly the temperature of the cold side will be relatively high. Since water is a much better conductor of heat than steam, it follows that the rapid removal of steam from contact with the heating surface, where it is generated, and its replacement with water will increase the transmission of heat into the boiler; that is, the capacity, and therefore the efficiency for a given output, will be increased.

But increased capacity and efficiency are not the only desirable results obtained by keeping the heating surface wet. Since, as stated above, the temperature of the cold side of the plate will rise if the substance on that side is a poor conductor of heat, it follows that the average temperature of the plate will also rise at the same time—that is, the plate will be overheated, which accounts for blisters and burns during forced firing. Therefore, from the three standpoints of capacity, efficiency and cost of maintenance there must be a minimum of retardation to the escape of steam from the tubes.

How is this accomplished in the Edge Moor boiler? It will be seen that the distinctive feature of this boiler is the extension of the headers, at full width, well above the tops of the drums so that, contrary to the usual construction, the drums with their full area enter the headers, giv-

ing a much larger throat as shown in the accompanying illustration. The importance of this greatly increased throat area from a theoretical standpoint is easily seen.



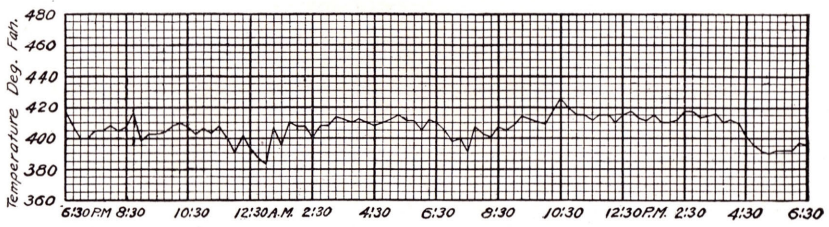
The principal distinguishing feature of the Edge Moor boiler is the unrestricted connection between header and drum

Consider what happens between the injection of a particle of water by the feed pump and its subsequent removal in the form of steam. At some place in the boiler this particle of water reaches the maximum temperature at which water can exist as a liquid in the same vessel with steam at a constant pressure. Sooner or later, it passes into one of the tubes, comes in contact with the hot surface and is transformed into steam.

Now this transformation is accompanied by a very great increase in volume. At 135 pounds pressure one cubic inch of water expands into 150 cubic inches of steam; at higher pressure the ratio of volume is somewhat reduced but is still very large. In consequence, the steam generated in the tube must leave the tube at a very much faster rate than the water coming into it. Now the faster a fluid moves, the greater is the frictional resistance which retards its passage and, since the

resistance to the flow of fluids varies as some power of the velocity, and since velocity must decrease as area increases, the rationality of making throat areas large to minimize the hindrance to the liberation of steam is very apparent.

However, it is always well to check theory with practice. For this purpose, the results of authoritative tests are here given. Since the true function of a boiler is to absorb heat from the gases produced in the combustion chamber, the index to the efficiency of a boiler is the temperature of escaping gases when they contain a high percentage of carbon dioxide, which is proof that the temperature of gases is a consequence of absorption in the boiler and not of infiltration of cold air near the breeching. Table I shows that gas temperatures have been obtained less than 60° above the temperature of the saturated steam, which is conclusive proof of the correctness of the principles underlying Edge Moor design.



TEMPERATURE OF FLUE GASES FOR FIRST 24 HOURS OF TEST NO. 8, TABLE I

TABLE I—SHOWING TEMPERATURES OF ESCAPING GASES FROM EDGE MOOR BOILERS

Test No.[1]	Per cent. of rated capacity developed	Combined efficiency Per cent.	CO_2 at damper Per cent.	Pressure of steam Lbs.	Temperature of saturated steam Deg. F.	Temperature of flue gases Deg. F.	Gas temperature − steam temperature Deg. F.
3	127	76.9	11.7	128	355	476 [2]	121
8	113.4	80.95	13.3	117.6	349	412	63
2	101.5	78.58	14.3	179	379	439	60
10	101.5	81.6	12.5 13.4	145.6	364	421	57

[1] See table on next page.

[2] Note that flue temperature is relatively higher when CO_2 is lower.

Table II is intended to show, primarily, the efficiencies obtained with Edge Moor boilers in different sections of the country. The efficiencies given are the *combined* efficiencies of the boiler and firing equipment, exclu-

TABLE II—TESTS OF EDGE MOOR WATER TUBE BOILERS

Test No.	Date of test	Name and location of plant	No. of passes	Kind of stoker	Kind of fuel	B.T.U. per lb. dry fuel
1	1909	United States Navy Yard, Philadelphia, Pa.	Four	Overfeed	Semibitum. coal	14,790
2	1914	Milwaukee El. Ry. & Lt. Co., Milwaukee, Wis.	Three	Underfeed	Bituminous coal	13,101
3	1908	Lardner's Point Pump. Sta., City of Philadelphia	Four	Overfeed	Semibitum. coal	14,770
4	1908	Lawrence Ave. Pump. Sta., City of Chicago	Four	Chain grate	Bituminous coal	11,557
5	1912	Dill & Collins, Philadelphia, Pa.	Four	Overfeed	Semibitum. coal	14,458
6	1916	Central Park Ave. Pump. Sta., City of Chicago	Three	Underfeed	Bituminous coal	11,962
7	1913	National Tube Company, Kewanee, Ill.	Four	Underfeed	Bituminous coal	11,048
8[1]	1913	National Tube Company, Kewanee, Ill.	Four	Underfeed	Bituminous coal	11,094
9	1911	American Ice Company, Philadelphia, Pa.	Three	Overfeed	Semibitum. coal	14,214
10[2]	1912	United States Navy Yard, Mare Island, Cal.	Four	Oil burner	California oil	18,790
11	1915	Cons. Gas El. Lt. & Pr. Co., Baltimore, Md.	Three	Underfeed	Semibitum. coal	14,454
12	1916	Sanitary District of Chicago, Chicago, Ill.	Three	Underfeed	Bituminous coal	10,624
13	1916	Sanitary District of Chicago, Chicago, Ill.	Three	Underfeed	Bituminous coal	11,000
14	1915	Hershey Chocolate Co., Hershey, Pa.	Three	Overfeed	Semibitum. coal	14,684
15	1915	E. I. Du Pont de N. & Co., Hopewell, Va.	Three	Overfeed	Semibitum. coal	14,032
16	1919	Mayfair Pumping Station, City of Chicago	Four	Underfeed	Bituminous coal	12,660
17	1917	Union Electric Lt. & Pr. Co., St. Louis, Mo.	Three	Underfeed	Bituminous coal	12,771

[1] Journal A. S. M. E., vol. 36, p. 220, 1914; and Bull. 53, Edge Moor Iron Co.
[2] Engineering News, vol. 69, p. 1126, May 29, 1913.

sive of the firing auxiliaries, as determined in practice and as defined in the Power Test Code of the American Society of Mechanical Engineers. The difference between combined efficiency and 100 per cent. includes, of

TABLE II (Continued)—TESTS OF EDGE MOOR WATER TUBE BOILERS

Test No.	Duration Hrs.	Temp. of feed water Deg. F.	Pressure of steam Pounds gauge	Superheat Deg. F.	Draft in furnace In.	Draft before damper In.	Temperature of flue gas Deg. F.	CO_2 at damper Per cent.	Rated capacity H. P.	Per cent. of rated capacity devel'p'd	Co'bined efficiency. Per cent.
1	12	52.0	142.6	79.4	0.21	0.39	468	.....	456	113.3	74.97
2	24	120.0	179.0	83.1	0.04	....	439	14.3	765	101.5	78.58
3	24	39.2	128.0	None	0.33	0.63	476	11.7	505	127.0	76.9
4	12	42.8	156.3	None	....	0.54	518	.....	279	158.0	74.7
5	24	80.3	110.6	None	0.24	0.45	521	10.7	749	116.4	77.9
6	24	158.8	149.3	113.1	0.01	0.16	436	12.7	497	121.0	75.29
7	24	183.9	116.0	91.2	0.01	0.28	450	13.0	613	127.9	80.38
8	72	194.9	117.6	77.9	0.01	0.26	412	13.3	613	113.4	80.95
9	12	155.4	144.9	None	0.15	0.33	...	.....	213	111.7	77.2
10	10	170.8	145.6	90.0	....	0.19	421	12.5 13.4	458	101.5	81.6
11	12	63.9	183.4	113.8	0.05	0.14	417	13.2	1047	130.5	77.3
12	13	169.9	154.2	86.7	0.05	0.19	429	12.0	499	125.8	78.2
13	23	170.0	153.8	86.4	0.02	0.18	438	10.6	499	108.6	76.7
14	12	55.6	162.5	83.8	0.19	0.29	477	14.0	410	108.9	76.3
15	9	195.6	132.0	None	0.51	0.82	539	.....	600	166.2	74.4
16	12	37.5	159.4	142.2	0.02	0.30	428	12.6	516	118.0	78.21
17	12	181.0	199.0	136.0	0.04	0.48	512	13.6	558	163.0	77.7

course, not only the loss due to escaping carbon monoxide, the loss from excess air, the loss from combustible to the ash pit, etc., which are chargeable to the furnace, firing equipment and firing labor, but also the unavailable heat such as the "hydrogen loss." By separate analysis of the performance of the boiler alone, excluding the losses chargeable to firing and unavailable heat, the efficiency of the Edge Moor boiler has been found to be much in excess of the combined efficiency.

As regards high overload capacity, Table III shows that tests have been made up to 328.6 per cent. of rating based on ten square feet of water-heating surface per horsepower.

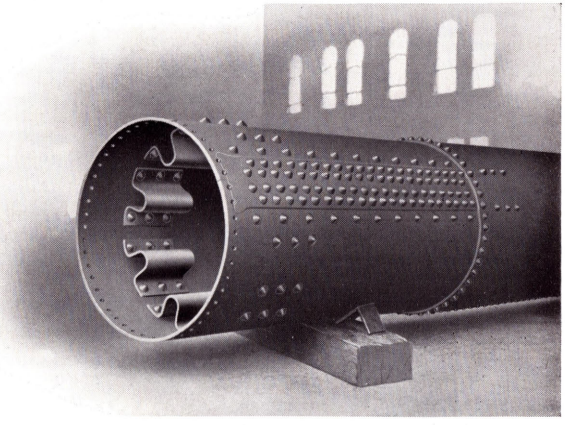
Another feature of boiler performance which must not be overlooked is quality of steam. Many official tests of Edge Moor boilers have shown that unusually dry steam is delivered—less than 1 per cent. of moisture being very common.

TABLE III—CAPACITY TESTS OF EDGE MOOR BOILERS

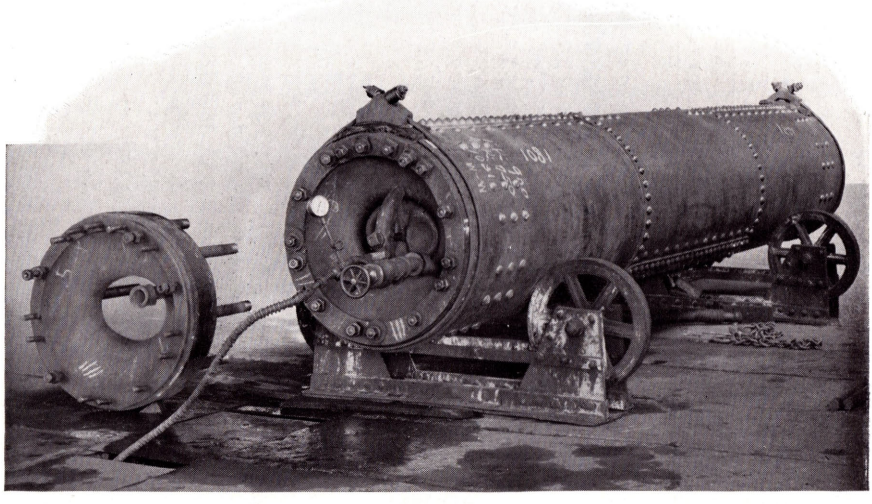
Name and location of plant	Date of test	Duration of test Hrs.	Rated capacity H. P.	H. P. developed	Per cent. of rating developed
Union Electric Light & Power Co., St. Louis, Mo.	1910	4	518	1265	244.2
Union Electric Light & Power Co., St. Louis, Mo.	1917	2	558	1834	328.6
Sanitary District of Chicago, Chicago, Ill.	1916	4	499	971	194.5
Consolidated Gas, El. Lt. & Pr. Co., Baltimore, Md.	1913	8	736	1829	248.5
Consolidated Gas, El. Lt. & Pr. Co., Baltimore, Md.	1913	2	736	2340	317.9
Consolidated Gas, El. Lt. & Pr. Co., Baltimore, Md.	1915	12	1047	2472	236.1
New York Steam Co., New York City	1917	240	1000	2070	207.0
New York Steam Co., New York City	1917	10	1000	2596	259.6

Materials and Workmanship

THE defects of an incorrect design can never be compensated for by workmanship or structural features, however good. But when it is recognized that the principles of design permit a realization of the best results, it is next in order to look into the various provisions for safety —the primary requirement, for accessibility for cleaning—which affects the efficiency and labor cost, and for conveniences for quickly taking a boiler out of service and putting it back—which affects the labor cost and the fixed charges.



Triple riveted, double butt strapped drum showing U-plates on the inside



Every drum is tested at the works with water under pressure to assure tightness of riveting before shipment

Copy of
Mill Tests of Material.

EDGE MOOR IRON CO.

Made by .....

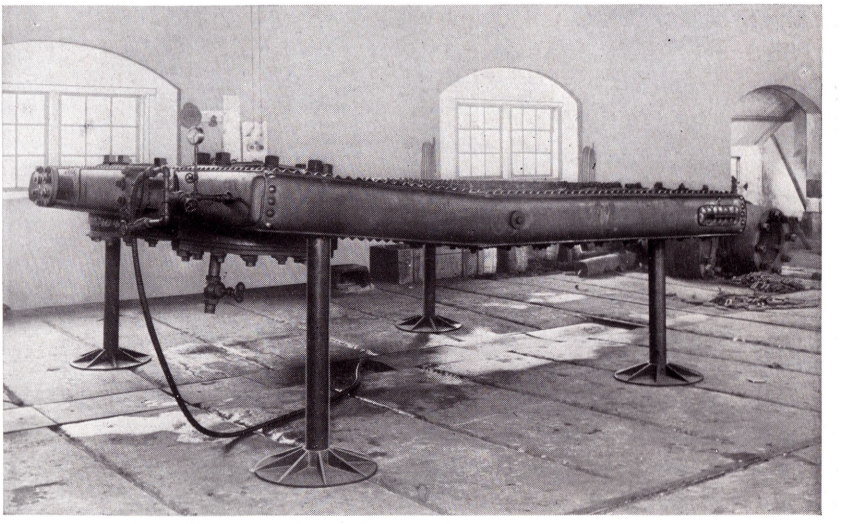
Boiler No. 1427 Order No. 1003 Date .....

HEAT NO.	MARKS.	SIZE.	Dimensions of Test Pieces: Width Inches	Tickness Inches	Area Square In.	Elastic Limit In. Lbs. Per Sq. In.	Breaking Strain In Lbs.	Ultimate Strength In Lbs. Per Sq. In.	Original Length Between Shoulders; In.	Final Elongation Per Cent.	Reduction of Area in per cent of original Area	Carbon	Phosphorus	Manganese	Sulphur	Appearance of Fracture	PART OF BOILER USED FOR
						FRONT HEADER											
2443	2A1	15'-4 3/4" x 59 1/2 x 1/2	1.530	.509	779	36070		55840	8"	26.0	57.6	18	012	37	029		Bulge Plate
1081	D1	15'-5 1/4" x 62 x 1/2	1.510	.509	769	33680		56440	"	29.0	59.9	18	020	30	033		Flange "
3537	2B1	15'-2 3/4" x 87 3/4 x 7/16	1.500	.450	675	36000		56000	"	28.0	60.0	18	015	34	022		Hand Hole "
3538	2G2	15'-2 3/4" x 87 3/4 x 1/2	1.545	.515	796	34420		58300	"	28.5	57.4	19	015	33	034		Tube "
4702	A1	16'-0 1/4" x 17 1/2 x 7/16	1.520	.447	679	35500		61860	"	27.5	52.1	19	021	34	029		Top Trough "
4702	A2	16'-0 1/4" x 17 1/2 x 7/16	1.520	.447	679	35500		61860	"	27.5	52.1	19	021	34	029		Btm. " "
4702	B1	11'-9 3/4" x 21 x 7/16	1.525	.445	679	36080		61860	"	28.0	53.5	19	021	34	029		R. Side " "
1035	B2	11'-9 3/4" x 21 x 7/16	1.570	.439	689	36000		57330	"	28.0	59.2	16	011	34	035		L. Side " "
						REAR HEADER											
4776	2A2	15'-4 3/4" x 59 1/2 x 1/2	1.475	.498	734	35430		55590	8"	30.0	59.9	17	016	38	039		Bulge Plate
3584	2D2	15'-5 1/4" x 62 x 1/2	1.510	.513	775	37810		61940	"	28.0	57.0	20	016	43	035		Flange "
4740	3FX	15'-2 3/4" x 87 3/4 x 7/16	1.505	.442	665	35190		59850	"	26.0	58.6	17	010	41	028		Hand Hole "
1035	2G1	15'-2 3/4" x 87 3/4 x 1/2	1.530	.501	767	33900		55800	"	26.5	59.2	16	011	34	038		Tube "
4702	H1	15'-2 1/4" x 22 1/2 x 1/2	1.520	.510	775	38290		61930	"	29.5	57.4	19	021	34	029		F. Throat "
1039	2H1	15'-2 1/4" x 22 1/2 x 1/2	1.370	.502	688	35610		61770	"	28.5	52.6	17	017	41	036		B. " "
3544	A1	16'-0 1/4" x 17 1/2 x 7/16	1.525	.448	683	33090		55340	"	30.0	62.4	16	013	37	035		Top Trough "
4702	A4	16'-0 1/4" x 17 1/2 x 7/16	1.520	.447	679	35500		61860	"	27.5	52.1	19	021	34	029		Btm. " "
4702	C1	13'-4 1/4" x 21 1/4 x 7/16	1.525	.445	679	36080		61860	"	28.0	53.5	19	021	34	029		R. Side " "
4702	C2	13'-4 1/4" 21 1/4 x 7/16	1.525	.445	679	36080		61860	"	28.0	53.5	19	021	34	029		L. Side " "

A first-class product must begin with carefully selected materials. Mill tests are required for every plate of an Edge Moor boiler

For safety, it is of the utmost importance that all materials shall be of homogeneous quality and of known strength and properties. The Edge Moor Iron Company requires tests of all plates and staybolt materials, and subjects such materials to critical inspection at its works before fabrication.

The Edge Moor boiler, exclusive of handhole plates, is strictly an *all steel* boiler, for not a particle of any such uncertain metal as cast iron



Every header is also tested at the works. Special testing equipment for both drums and headers are required for this purpose

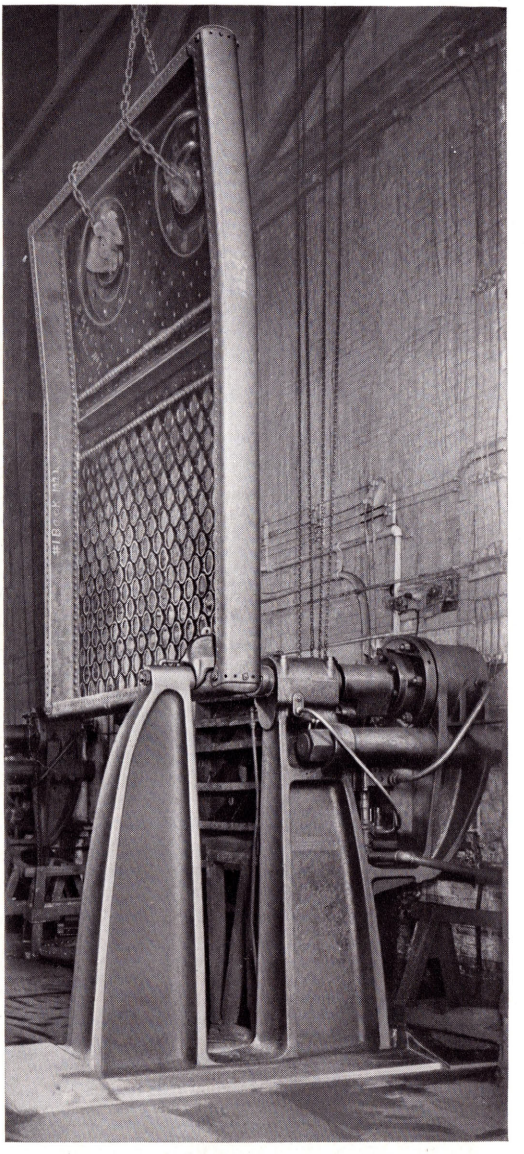
enters into its construction. Handhole plates, which are in compression, are furnished of either cast iron or forged steel, as the purchaser desires.

Two other primary structural factors are riveting and the staying of flat surfaces. With regard to riveting, it is a standard practice with the Edge Moor Iron Company to first punch guide holes for the drill, $\frac{1}{4}$ inch smaller than the finished rivet holes, in only one plate of a joint.

The plates are afterward bolted together, and the rivet holes are drilled through the lapped plates *at one operation*, assuring a perfect match of holes and thus eliminating the possible future use of the injurious drift pin. The plates are then taken apart, all burrs and chips are scraped off (only those who have seen the accumulations on the dismantled plates will appreciate the importance of this step) and the plates are reassembled for riveting.

All rivets are of standard soft steel, brought to the proper heat before riveting, driven by an hydraulic riveter wherever possible, or by a pneumatic hammer, and held until black. The tightness of all joints is proved in the final shop tests.

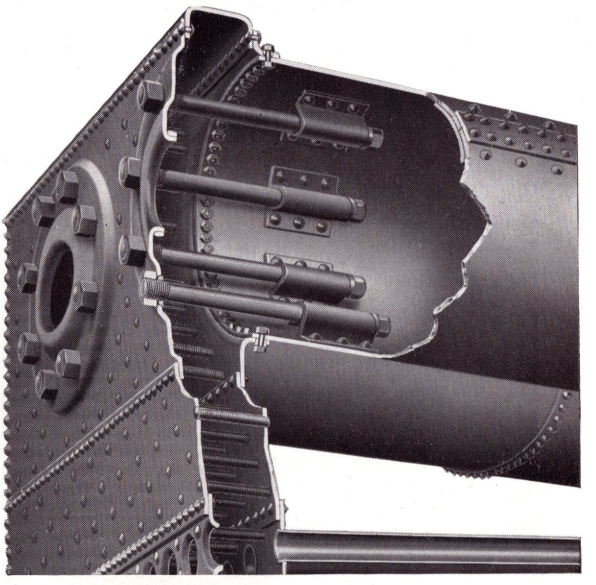
The accompanying engravings show clearly the manner of staying the headers. Just as for effective designs in building and bridge construction, it becomes necessary to make use of built-up girders instead of rolled beams, so in boiler construction it is necessary to resort to stayed surfaces when the space limitations of small containers, cylindrical and spherical walls, and the uncertainties attending their construction, stand in the way of carrying out a design that will give added strength and efficiency.



An example of high-class workmanship. The hydraulic riveter is used wherever possible

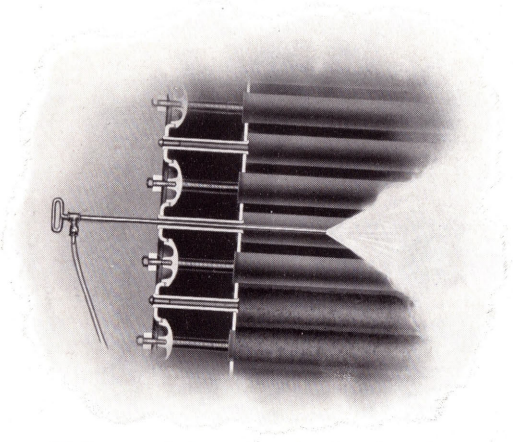
A cable built up of strands of small wire is far stronger and more reliable than a solid wire of the same cross-section, because of the greater certainty of the strength of all parts. The same is true for built-up boiler headers as against those cast or forged to a single piece. The statistics of the boiler insurance companies with regard to the causes of accidents fully substantiate this point.

The bulges opposite the drums of Edge Moor boilers are effectively stayed by eight steel bolts, $2\frac{1}{2}$ inches in diameter, anchored through steel U-plates riveted to the inside of the drum. The joint in the header plate is made permanently tight by the use of an annealed copper cone-nut which is drawn into the conical hole in the plate by screwing up on the outside nut before the staybolt is anchored.



Edge Moor headers are stayed in a most effective manner

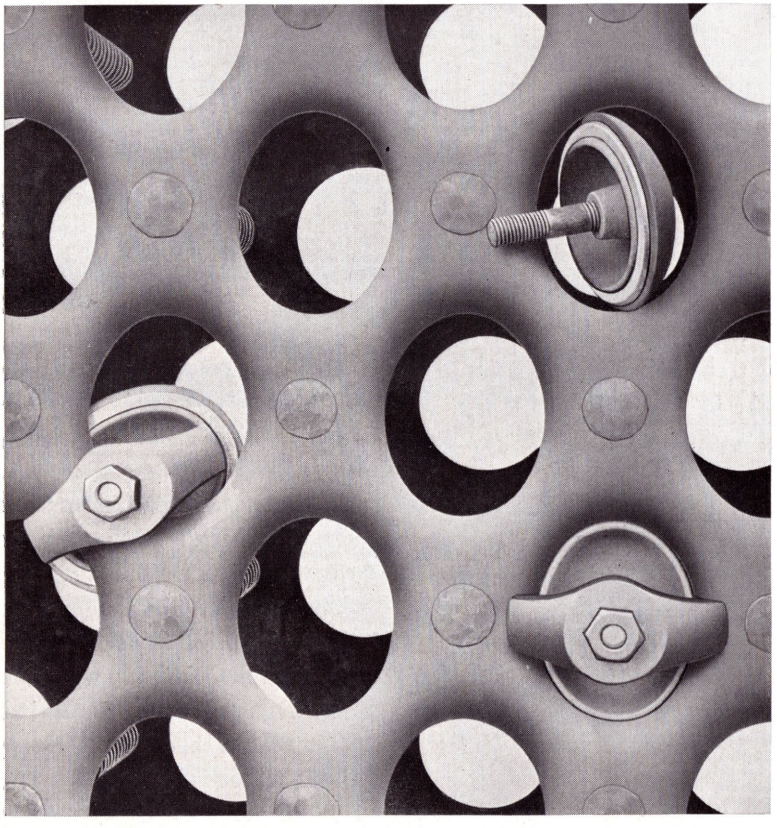
The other parts of the header are stayed by bolts of proper cross-section installed as follows: After the staybolt holes are drilled and the header plates are riveted together, the headers are set on edge, and opposite staybolt holes in both plates are first reamed and then tapped by the continuous travel of a special combined reamer and long tap which passes through the staybolt holes in both plates and thus threads the opposite plates as if they were in the same piece of metal, making it possible to screw in the staybolts without forcing. Staybolts cut to size and threaded throughout their length are then screwed in place and the projecting ends are riveted over and caulked to make the joints tight.



Hollow staybolts are used when the tubes are to be dusted from front or rear

The Handhole Plate

TOO often, boilers are bought "by the horsepower." Considerations other than the price and the heating surface are given scant thought,

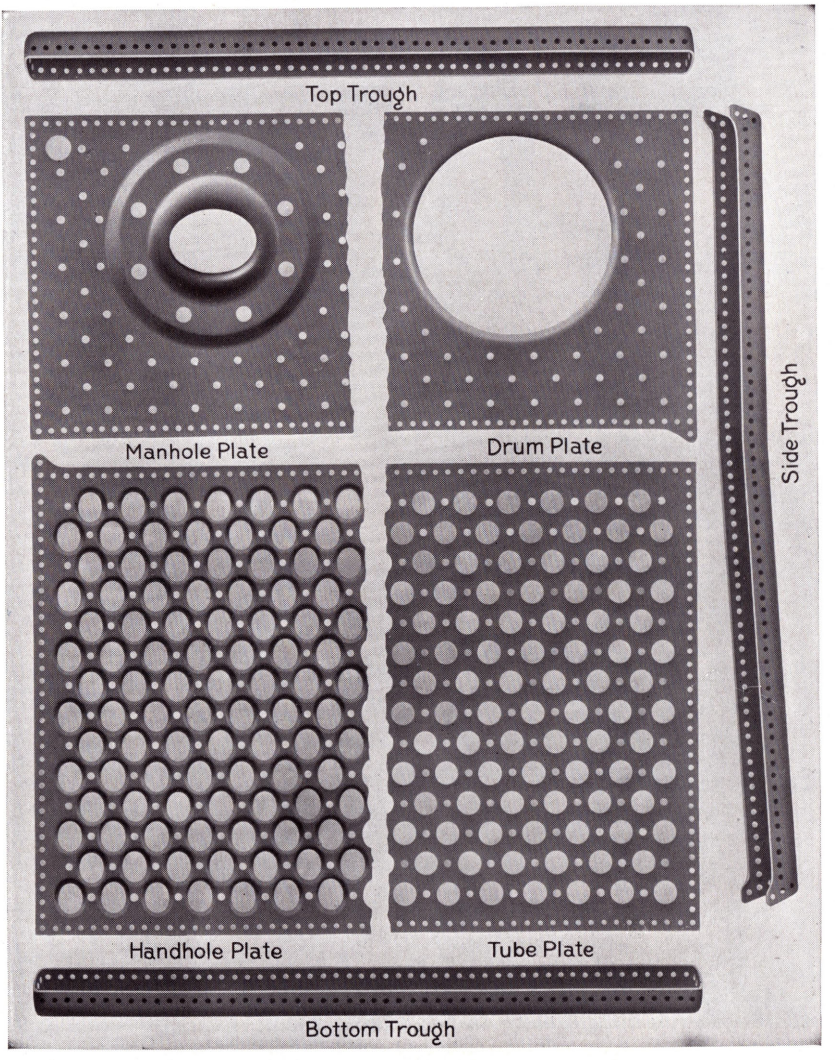


Elliptical handholes make it possible to remove any cover without disturbing any other cover resulting in a saving of time and gaskets

with the result that several times the additional cost of a superior boiler may be wasted annually for extra fuel and maintenance.

A feature of Edge Moor construction that affects maintenance, and one worthy of especial notice is the handhole plate. Every handhole is elliptical to make it possible to pass every cover through its own hand-

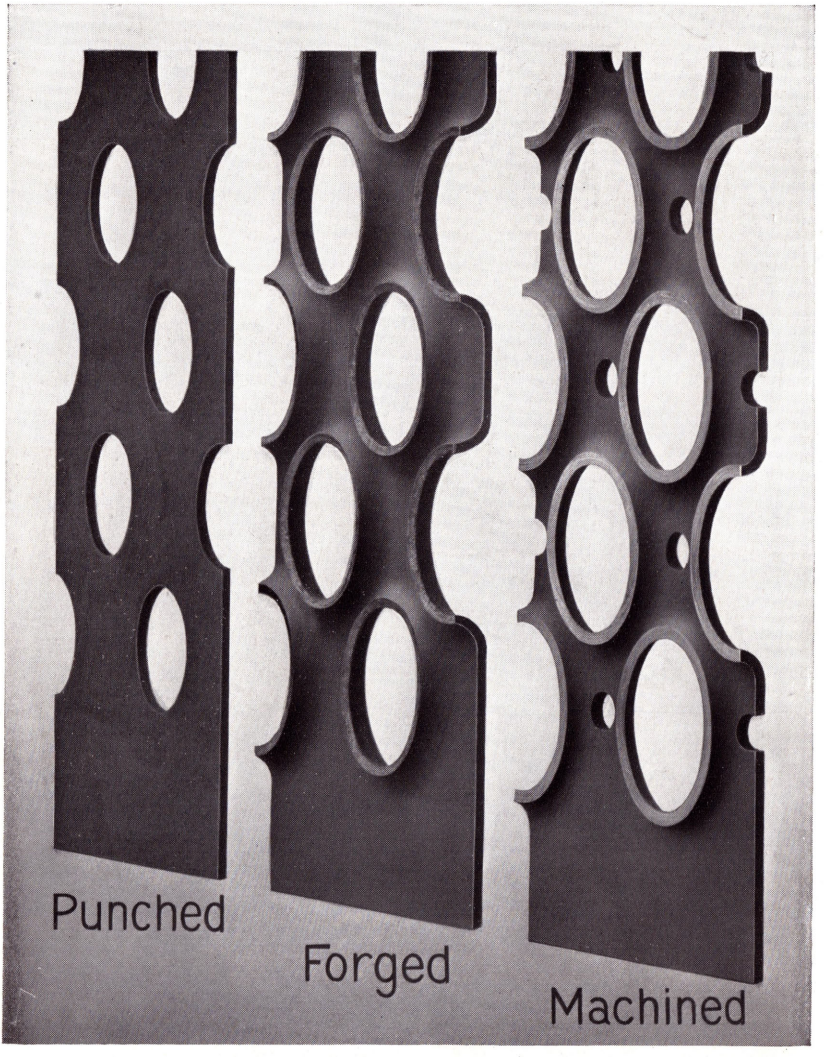
hole, instead of from one hole to another, as in those boilers where, for the sake of cheapening the cost of construction, most of the holes have



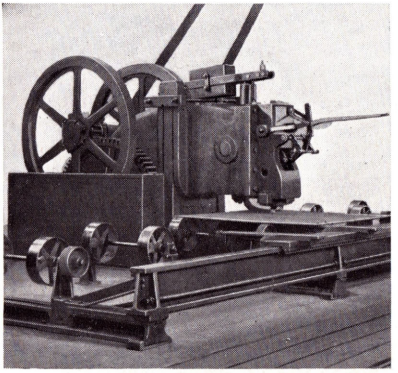
PARTS OF AN EDGE MOOR HEADER

Visitors at our shops are impressed with the workmanship that gives Edge Moor boilers distinction

been made circular with an elliptical or heart-shaped hole here and there to enable the covers to be removed. Such cheapened construction requires,



Every handhole plate is fabricated in three stages

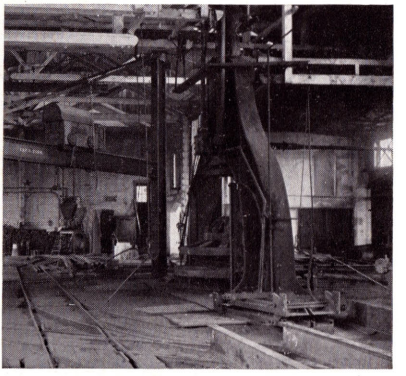


Elliptical holes are first punched in the blank plate by means of a combined punch and spacing mechanism

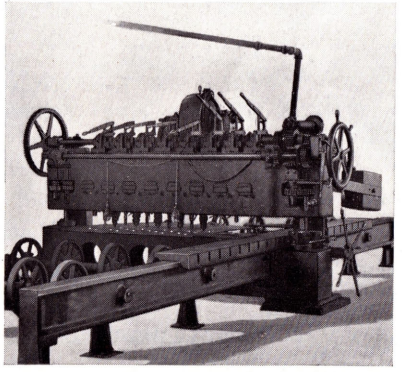
of course, much extra labor to open and close up a boiler during the inspection and cleaning periods.

It will be noticed that the covers bear against the inside of the header plate which makes their factor of safety independent of the strength of the studs or dogs. Should, by accident, a stud break when being set up while a boiler is under pressure, the joint will still remain tight, for the cover is held against the plate by the internal pressure. No special make of gasket is required with Edge Moor boilers. The purchaser may use any satisfactory gasket, provided it is made to fit the cover.

Returning to the construction of the handhole plate, it will be seen that the edges of the holes are flanged inward. This is done by means of dies after guide holes have been punched in the plate and it has been heated to the proper temperature for flanging. After the flanging, the plate is sent to a specially constructed multiple spindle machine which faces the upturned edges to smooth, plane surfaces. The flanging greatly stiffens the plate to resist the internal pressure of the water and to prevent the springing of the faces of the handholes while the plates are being set up against the gaskets—a workmanlike construction, assuring tight joints.



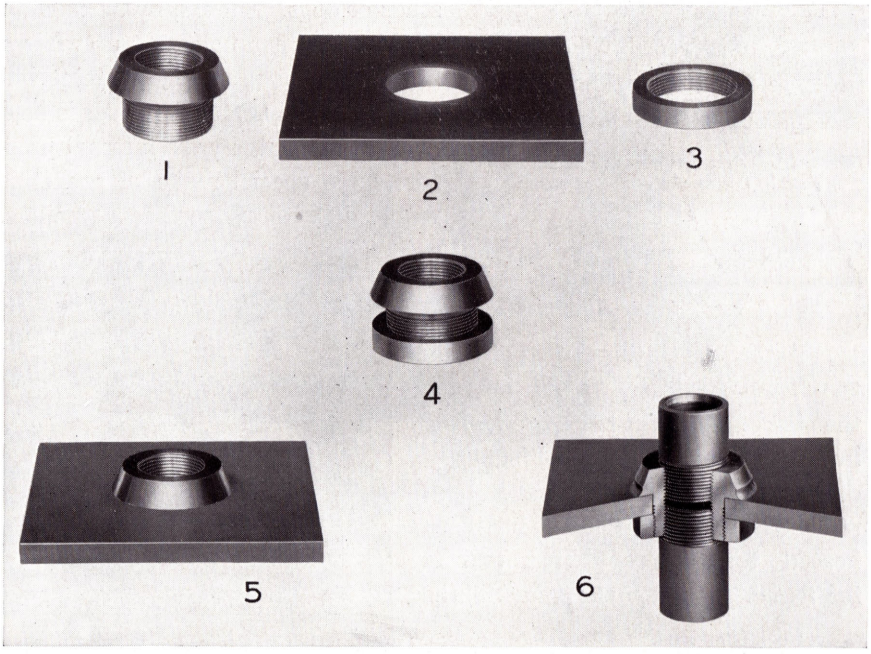
The plate is then heated to a cherry red and the holes are forged to shape between multiple dies



A multiple spindle machine faces the edges and automatically spaces and drills the holes for staybolts

Miscellaneous Details

ONE of the unique structural details of the Edge Moor boiler is the patented pipe connector. This takes the place of the commonly used reinforcing pad wherever there is not sufficient thickness of metal for

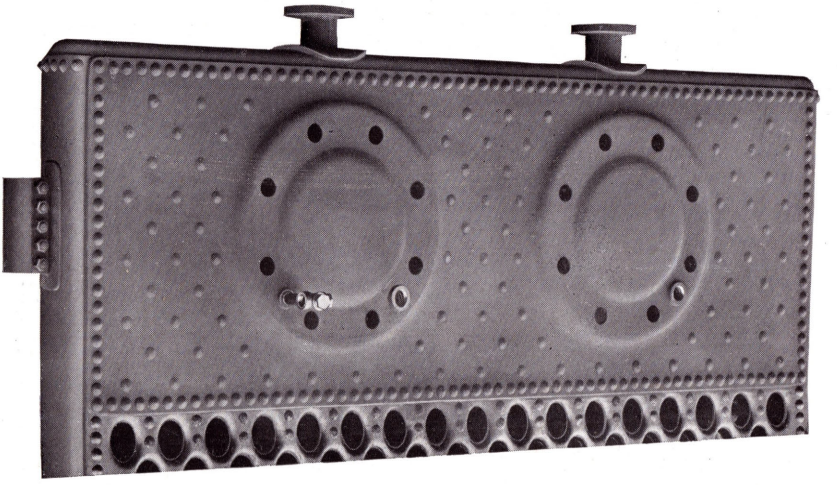


PATENTED EDGE MOOR PIPE CONNECTOR

1. Pipe connector 2. Plate to be reinforced 3. Lock nut 4. Lock nut on connector 5. Connector in place before caulking 6. Connector after caulking, showing pipes in place

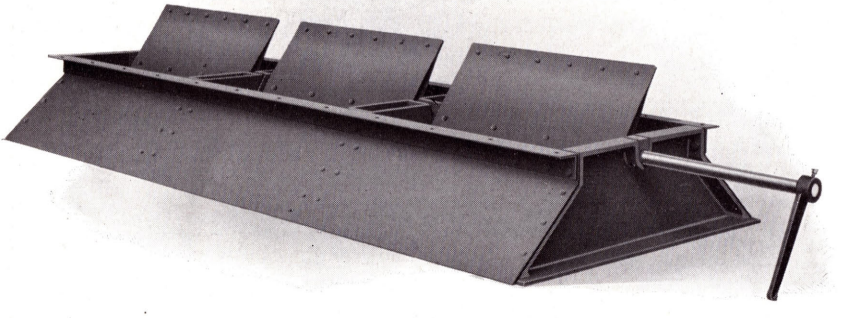
the larger pipe connections. For attaching the feed-water, water-column and surface blow-off piping, these connectors are ideal. They are made of steel, are very simple in construction and present a workmanlike appearance.

The method of installation is as follows: Referring to the engraving above, a straight circular hole *2* is first bored through the plate to be reinforced. The connector *1* is then passed through this hole, as at *5*, and locked in place by the nut *3*, as shown in *6*. This nut is threaded for an easy fit,



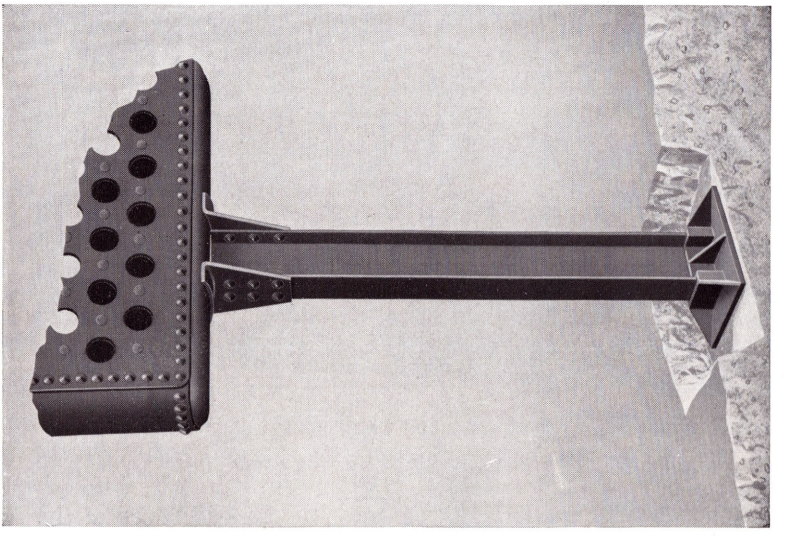
These connectors, for feed water and water column piping, are a decided improvement on the commonly used reinforcing pads

so it may be screwed up by hand. Finally, the bevelled edge of the connector is fullered and caulked against the plate to make a tight joint. The fullering causes the connector to fit snug against the plate and is equivalent to screwing up the lock nut with considerable force, so much so that the connector can only be removed by cutting the nut apart.

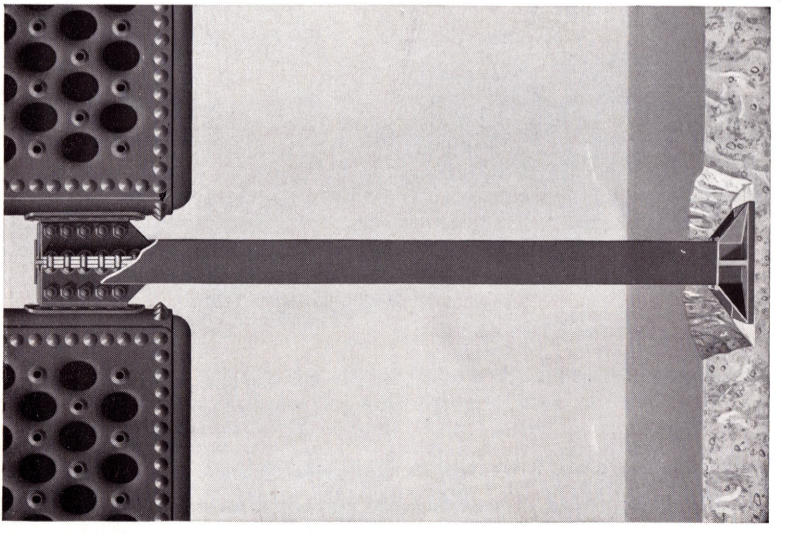


Uptake and damper furnished when the gases are to pass out of the top of the setting

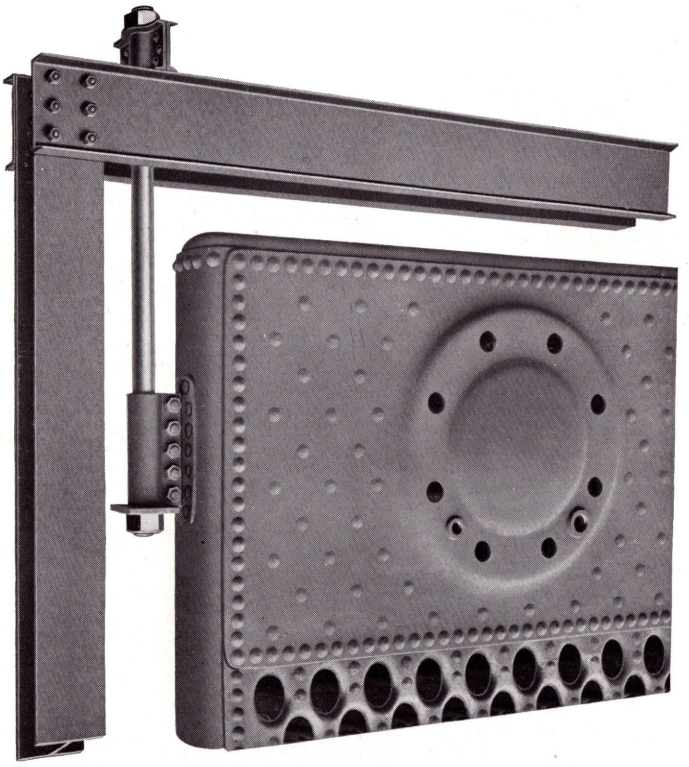
Owing to the ease with which connectors may be installed, they are especially suitable for any additional connections that may be desired during or after erection. They are to be found only on Edge Moor boilers as the patent is the exclusive property of the Edge Moor Iron Company.



Saddle type of support for rear headers



H-column support for battery of boilers

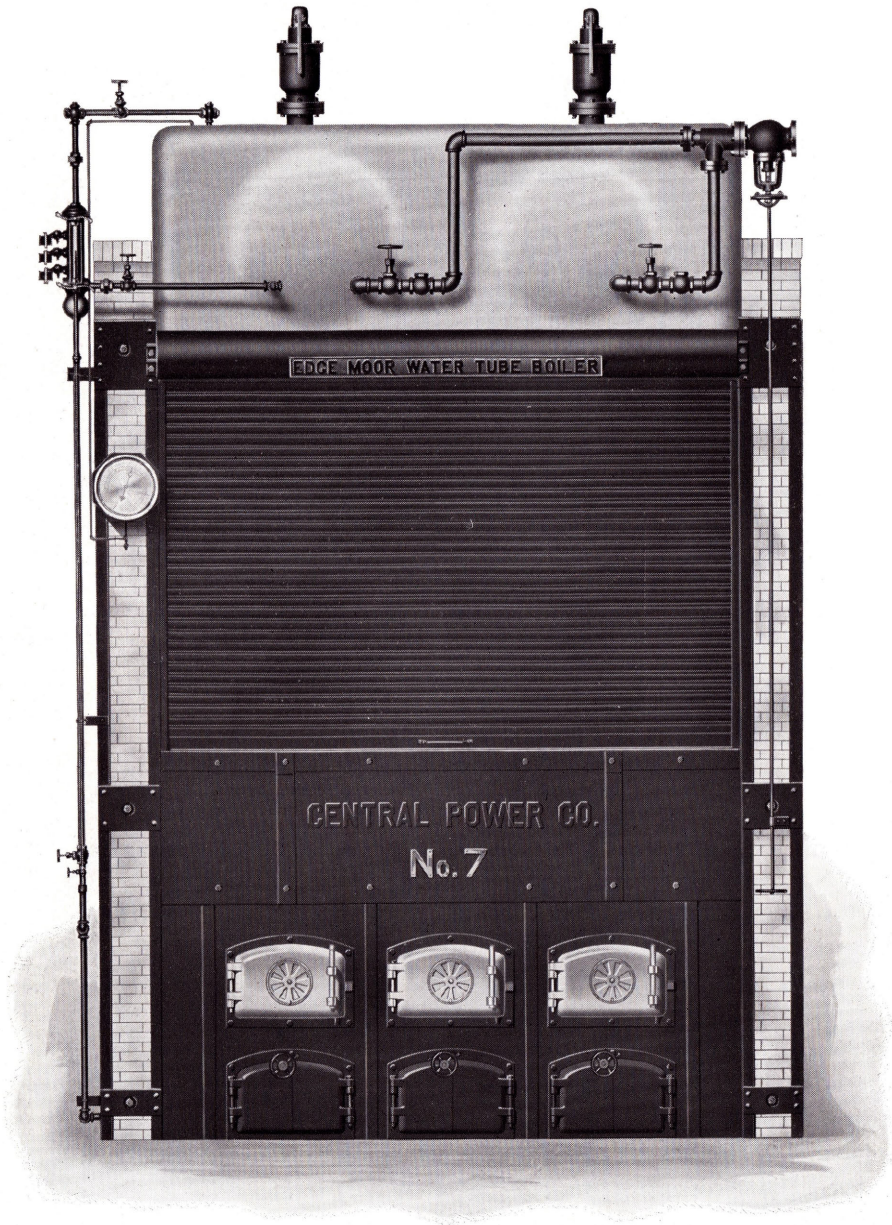


Standard method of suspending Edge Moor boilers

Edge Moor boilers are either supported by columns or hung from overhead beams. The method selected for an installation will depend on the special conditions to be met. In all methods the columns terminate in cast iron base plates set in the foundations and are not connected to, nor do they rest on, the brickwork of the setting.

When boilers are supported or hung from the sides, the initial connection is a specially constructed steel tee riveted to the side trough of the header. This is bolted to the connecting angles on the column supports or, in the suspended type, to the steel sleeve through which the hanger bolt passes. This bolt terminates at both ends in ball-faced nuts which fit into correspondingly recessed washers to facilitate readjustment when the boiler expands or contracts.

The design of other details such as front castings, manhole doors, tube dusting frames and parts, etc., conforms to the high character of the boiler proper. The customary fittings are of the best standard makes.

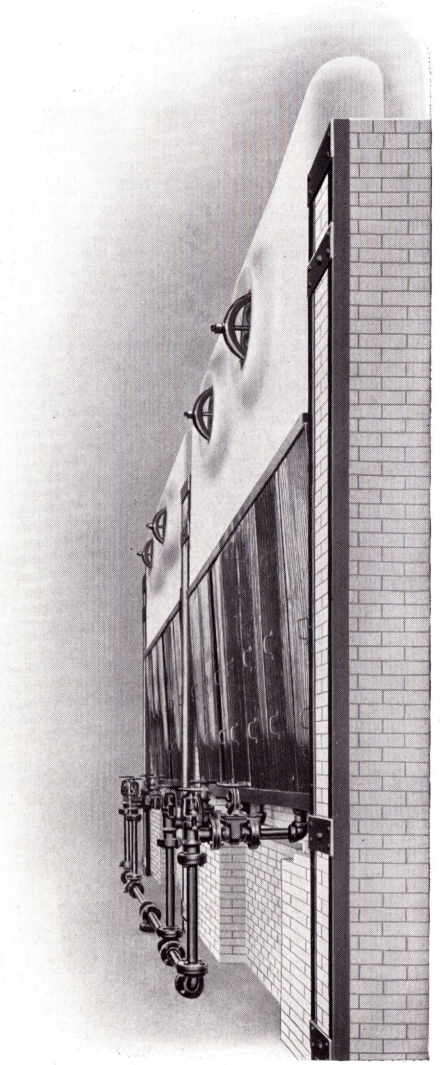


Standard front of an Edge Moor boiler

As these engravings show, the details affecting the external appearance of the Edge Moor boiler have been designed to combine strength with utility and pleasing appearance. The ends of the longitudinal walls terminate at both front and rear in pilasters built up of steel angles and plates. Tie rods connect front and rear pilasters to strengthen the wall against cracking.

For insulation and appearance, and for quick access to all of the handholes of the front header, a strong and attractive metal rolling door, such as is often seen at entrances to warehouses and other fire-proof structures, is mounted between the front pilasters. The door rolls upward into a cylindrical shell and is therefore entirely out of the way when open.

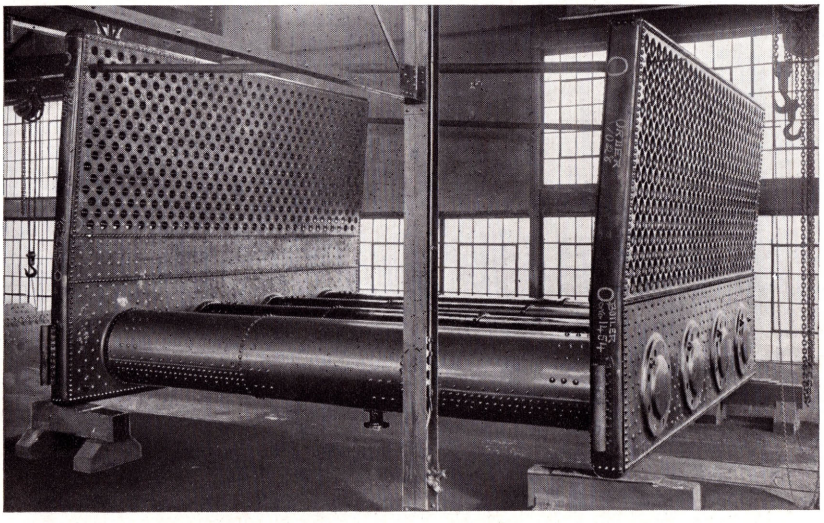
Opposite the rear header sectional doors, built up of corrugated iron, are used. These are fitted with handles so they may be conveniently taken out and set to one side.



Rear view of a battery of boilers

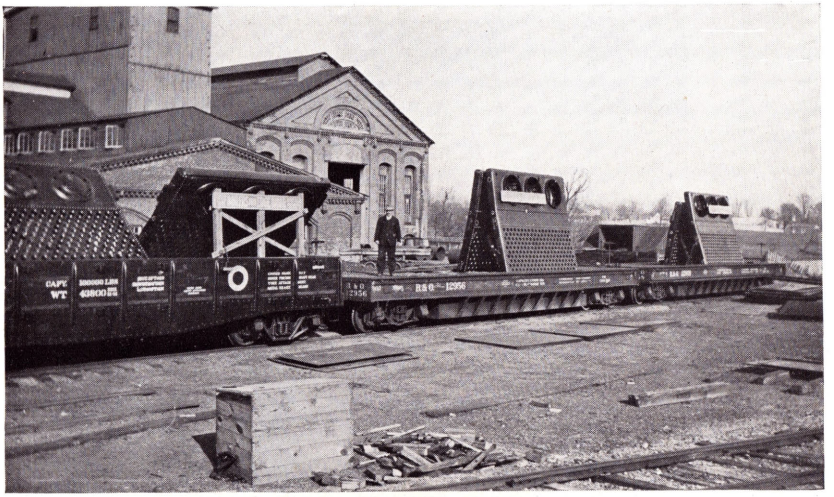
The upper parts of the headers are usually covered with non-conducting covering, about two inches thick, neatly troweled to a hard finish. The spaces between headers and brickwork are packed with asbestos fibre to prevent leakage of air.

The complications that are apt to arise during erection are avoided as much as possible by fitting the different parts in the shop and reducing the field work to a minimum. As the illustration below shows, the headers and drums of each boiler (the one shown is a four-drum boiler having 10,490 square feet of water-heating surface) are put together in the assembling shop, accurately aligned, and then the holes for connecting the drums to the headers are drilled continuously through the lapped joints to assure a perfect match of holes. The headers and drums are afterward taken apart and prepared for shipment.



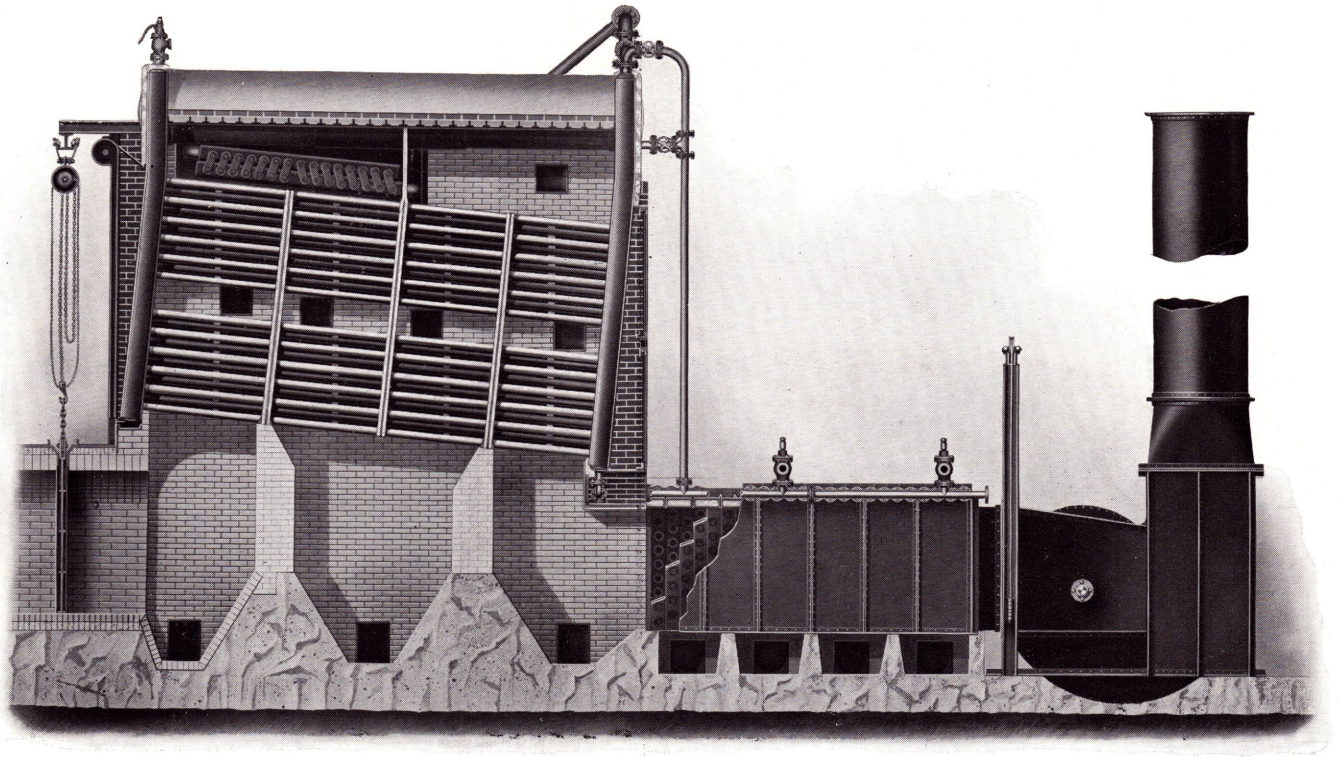
All headers and corresponding drums are invariably assembled in our shops. This is done upside down for convenience in drilling the holes through header flanges and drum ends

With the exception of the very smallest sizes, Edge Moor boilers are shipped from the works in "knocked-down" condition. Parts are of such size and weight that they can be easily removed from the cars and transported to the boiler foundations, whether in basement, at ground level or in upper stories. The field erection is simple, requires very little skilled labor and may be carried out with great expedition. By means of the method of connecting drums to headers, all riveting in the field is avoided and only a very little caulking is required.



Typical loading of large Edge Moor headers

Shipment of three 600 horsepower boilers leaving the works



An Edge Moor waste-heat unit, including boiler, superheater, economizer, fan and shut-off dampers

The Edge Moor Waste Heat Boiler

IN the manufacture of certain products, especially steel and cement, millions of dollars' worth of fuels are annually converted into gases which leave the manufacturing equipment at a temperature between 1000 and 1500 deg. F. and are discharged into the atmosphere. The possibility of recovering a large part of the heat thus wasted has long been realized but the development necessary for a high economic return has been reached only in recent years.

The design of an efficient waste-heat plant involves many special problems. This is particularly true for cement mills, on account of the very considerable quantity of dust carried along with the gases. (In one mill this dust averaged about 30 pounds per barrel of clinker burned.) The Edge Moor System for waste-heat recovery embraces the complete installation, from the ends of furnaces or kilns to the fan outlets. The illustration on the opposite page shows a complete Edge Moor waste-heat unit, including boiler, superheater, economizer and fan. Descriptions of the auxiliaries to the boiler are beyond the scope of this bulletin, but may be found in a special bulletin devoted to waste-heat recovery, which will be sent on request.

The early installations of waste-heat boilers were very crude because certain laws of heat transmission were not understood and insufficient attention was given to important details. The design of an efficient direct-fired boiler plant of the ordinary type and the design of an efficient waste-heat boiler plant are and should be very different. In the former, the gases approach the boiler at a temperature which may be as high as 3000 deg. F., while in the latter the gases enter at a temperature between 1500 and 1000 deg. F. As a result, the average heat transmission per square foot of boiler heating surface is much greater in the former than in the latter.

In earlier installations it was common practice to allow about 20 square feet of heating surface per boiler horsepower. As a result, boilers were relatively very large, had relatively large settings which increased the associated losses, and consequently produced a small net gain.

Since then the laws of heat transmission are better understood. It has been found that the heat transmitted per square foot of boiler surface can be greatly increased by increasing the gas velocity across the surface.

Roughly speaking, if the velocity can be increased three times, the heating surface can be reduced one-half. Also, by making the gas passage longer, the amount of heat abstracted is likewise increased. The application of these principles in the Edge Moor waste-heat boiler is largely responsible for its efficient performance.

The structural features of the Edge Moor boiler make it especially suitable for waste-heat recovery. Excepting certain necessary modifications, the parts are of the same standard design as for the direct-fired Edge Moor boilers commonly used in power plants.

The design differs for waste heat in that headers are built much higher and relatively narrower, and tubes are longer, to obtain by suitable baffles the high gas velocity and long gas path necessary for a high heat transfer.

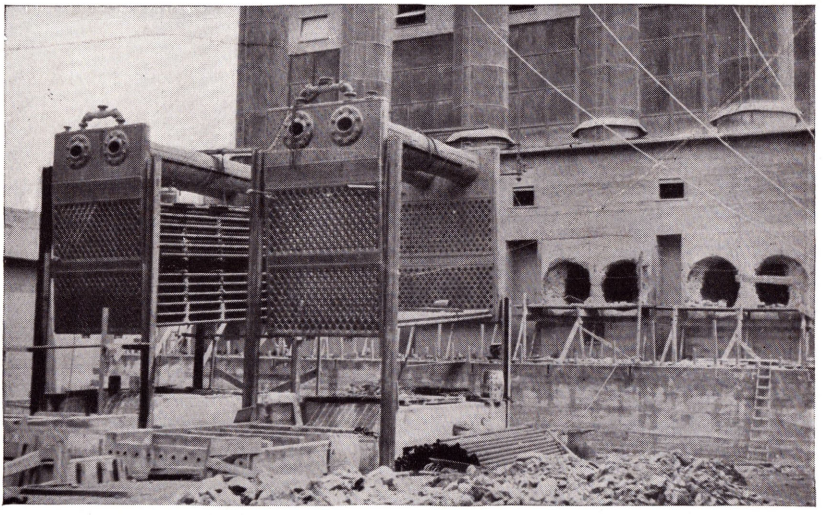
The headers are continuous throughout their entire height and width and therefore have no packed joints in their faces through which cold air may pass into the setting.

The baffles are easily installed and kept tight to prevent short circuiting of gas. Baffles are straight, almost vertical, and the bottom of each pass is a clear opening through which deposits drop or are forced by the high gas velocity to the deep pits below. Also, there are no ledges or pockets where deposits may accumulate.

The setting is such that equipment for hand or mechanical blowing may be installed for maximum efficiency and convenience of the operator. The provisions for internal cleaning are likewise favorable. Tubes straight throughout their entire length and handhole plates individually removable make internal cleaning convenient and efficient.

An important advantage of the general design of the Edge Moor boiler is that all parts may be readily inspected to see the actual condition, instead of "guessing" at it. This is highly important for proper maintenance of plant. The diagonal rows of tubes are parallel, with clear spaces between them; hence the inspector may see all of the exterior heating surface. Also, he can conveniently see both sides of the baffles, as well as the junctions between the baffles and the bridge and sidewalls. Unless baffles and junctions in a boiler are kept tight, the gas will short-circuit through the boiler with consequent decrease in the steam production. The inner surface of the tubes is also easily inspected. By having a light at one end of a tube and looking through the other, all tubes being straight, the internal condition of the tubes may be positively known.

The importance of waste-heat equipment in conserving fuel resources is indicated by the following calculation for a single cement mill of average



Edge Moor waste-heat boilers in course of erection

size. The estimated net steam production from waste heat in a 4000-barrel mill is about 53,000 pounds per hour, from a feed water temperature of 200 deg. F. to a pressure of 200 lb. per sq. in., gauge, and 100 deg. of superheat. This is exclusive of the steam consumed by the fans, and is therefore available for power.

A modern stoker-fired boiler plant without economizers will consume about 115 pounds of 13,500 B.T.U. coal per 1000 pounds of steam generated, or 2.7 long tons per hour for an hourly net steam production of 53,000 pounds. Hence if the steam required for power is generated from waste heat, instead of by a modern stoker-fired boiler plant, the saving of fuel for the 4000-barrel mill should be as follows:

Estimated saving of coal per 24-hour day	65 long tons
Saving per 300-day year	19,500 long tons

It has been estimated that the cement industry in the United States consumes over two and one-half million tons of fuel for power purposes only. Since all or nearly all the power required by cement mills can be generated from the waste-heat in the kiln gases, the two estimates given above show that extensive use of waste-heat equipment will go a long way toward solving problems of fuel shortage and conservation, besides producing a considerable reduction in the cost of the manufactured product.

Instructions for Care and Operation of Boilers

THESE instructions are intended to supplement the common instructions for operating steam boilers, the local inspection laws and the rules of the insurance companies. The old saying, "A stitch in time saves nine," is probably truer of a boiler than of any other piece of machinery. Clean a boiler often, and the work of keeping it clean is easy; but let a boiler be neglected for several months, then the work of getting it back into good condition again becomes, indeed, a difficult job. Nature invariably exacts a heavy toll for inefficiency and neglect. In the case of boilers, that toll is always paid by waste of heat up the chimney, by expense for repairs which could be avoided, by loss of capacity, by inexcusable shutdowns, and in other ways. Surely, the efficient way is the only way.

Before putting a new boiler into service, clean out all dirt and loose objects from the drums, headers and tubes. Wipe out any oil that may have been spilled during erection. See that the water column, feed and blow-off connections are clear. See that all internal fittings are securely fastened. Inspect the outside of the boiler and remove all mortar, dirt and asbestos sticking to or resting on the boiler parts.

New brickwork should be dried out slowly, otherwise bad cracks will result. A good way to do this, and to clean the inside of the boiler at the same time, is as follows: Put about one-half peck (four quarts) of soda ash into each drum before closing up. Open the air vent and pump clean water into the boiler up to the second gauge cock. Then proceed as follows: Slack off the buckstays to allow the walls to readjust themselves while being dried. Build a small wood fire on the middle of the grate (keep fire away from furnace walls) and keep the fire burning slowly until the steam pressure is about ten pounds. This should take a whole day or longer. Then let the fire die out, shut the air vent, leave the damper wide open, shut all furnace and ash-pit doors but one, leave this one open just enough to allow a little air to pass through, and let the boiler stand. The heat in the boiler, together with the passage of air, will continue the drying after the fire is out.

When the boiler is cold, let the water run out to get rid of the soda ash and the oil and other matter which has been loosened by the boiling solution. Refill with fresh water, build another slow fire, and repeat as above. Unless the brickwork is very damp, two dryings as above will be sufficient

but the boiler should be run light during the first few days of service. Finally, empty the boiler, remove a few bottom handhole plates from both headers, and clean out all dirt from the bottom header troughs. Examine the joints between baffles and bridge and hanging walls, and fill up all shrinkage cracks. Tighten the buckstays and through rods, and follow up occasionally. The boiler may then be put into service.

Do not leave anything loose in a boiler. Nuts, bolts, tools, etc., left in a boiler may wear away the metal by continuous rubbing.

Never install a handhole or manhole plate without first coating the threads of the stud or bolt with a mixture of graphite and boiled linseed oil. If this is not done, the nuts will rust on, making it difficult to back off the nuts, and often resulting in twisted or broken studs or bolts.

Watch the handhole and manhole plates when steam is being raised and tighten those that leak, but do not put too great a strain on them. A little sidewise rapping on the plate before tightening up will often cause the gasket to readjust itself and will help to stop the leak.

Aim to keep two gauges of water in the glass continuously. Do not install feed water regulators which permit considerable variations of the water level. If more than one boiler is in use the feed pump should be controlled by a good pump governor.

When a boiler foams, try to stop it by blowing off. Check the fire and shut the steam outlet valve long enough to determine the amount of water in the drums. If there is sufficient water, blow off several inches, feed in fresh water and repeat several times. Use the surface blow-off, if there is one, as the cause of foaming is usually scum on the surface of the water. If blowing off does not stop the foaming, the proper thing to do is to cool the boiler, empty it, clean the inside and refill with fresh water.

When the action of engines or turbines indicates wet steam and the water levels in the boilers are not fluctuating, examine all automatic drains on the steam piping and make sure they are working. It has often been found that wet steam was caused by accumulations of water *beyond* the boiler, due to a defective drain or pockets in the piping.

Take a boiler out of service as soon as possible after a leak is discovered, for if the steam or water is allowed to blow for any length of time, the metal may be worn away to such an extent that expensive repairs will be necessary.

Blow off a boiler often enough to keep the water from getting foul. The best time to use the blow-off is when there is little or no circulation in the boiler, as when the fires are banked. If the sediment and scum are

allowed to settle before blowing off, more will be ejected with less waste of water. It is common practice to blow off about four inches of water for every eight hours of service, but this may be too much or too little, depending on the amount of solid matter in the water. Blowing off is helpful for a limited time only. There comes a time when the boiler should be emptied and refilled with fresh water. In some plants the water is so bad that it is necessary to do this as often as once a week.

Where the water is bad it is desirable to put a tee above the drain valve on the water column blow-off and to connect thereto a nipple and a valve for drawing off samples of water. Blow out the water column thoroughly; then draw off a bucket of water; examine it for sediment, oil, etc., and do what is desirable to improve the water. Doing this regularly will often prevent priming, blistered tubes, corrosion and the carrying of solid matter into superheaters, engine cylinders, turbine blading, etc.

Take boilers out of service often enough to prevent excessive accumulations of mud, scale and soluble salts, and clean them outside and inside. It is good practice to turbine the two bottom rows of tubes at intervals of from one to three months, and the entire boiler once to three times a year. The frequency of cleaning should depend, of course, on the amount of solid matter in the water which cannot be blown off.

Cool off a boiler before emptying it. Let the brickwork and boiler cool as long as possible before the water is run out. If a boiler is emptied while hot, the scale and mud will bake on, and the work of cleaning will be greatly increased. Never empty a boiler when the steam pressure exceeds ten pounds, and never pump cold water into an empty boiler before the boiler and setting are cold throughout.

Never use a steam soot blower when the fire is out, when the fire is banked, or when the fire is light, as the steam will be chilled, producing moisture which will cause the particles of soot and ash to cement together and stick to the tubes in lumps. Use the blower only when the boiler is steaming at a good rate, at which time the gases will be hot and will have sufficient velocity to carry away the soot as it is dislodged. Use air if the boiler must be cleaned while out of service. When there are no mechanical soot blowers, each boiler should be cleaned once a day with a hand blower. Clean the first pass first, then the second, etc., following the travel of the gases.

Keep cracks and open joints in the brickwork filled up, especially in the furnace. Occasionally explore the outside of the setting with a lighted candle while the boiler is in service. The suction of the candle flame will

indicate bad air leaks. Do this especially when there is lack of draft and the combustion is not good.

Inspect the baffles and tubes frequently and keep them in good condition. Some of the baffles and sections of tubes in the first pass can be inspected by the light of the fire while the boiler is in service by looking through the soot cleaning ports or hollow staybolts, and all parts of baffles and tubes can be thoroughly inspected when the boiler is cold, by shining an acetylene light between diagonal rows of tubes, or by fastening a tubular electric lamp to a stick and using it in the same way.

Treat the feed water logically. Water usually contains sludge and scale-forming matter as well as substances which may cause corrosion or priming, but the amount of any one substance may be so little as to cause no trouble or may be so great as to make the water entirely unfit for boiler purposes. Each water must be treated to eliminate or weaken the *particular* troublesome matter which it contains. That is why a method of treatment that is very successful in one plant often turns out worse than a failure in another.

Edge Moor Iron Company

Designers and Builders of

Edge Moor Waste-heat Plants and the Edge Moor Water Tube Boiler

SALES OFFICES

Boston	79 Milk Street
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Chicago	10 S. La Salle Street
St. Paul	Robinson, Cary & Sands Co.
Charlotte, N. C.	Thomas B. Whitted

Main Office and Works

Edge Moor, Delaware